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A novel business context-based approach for improved standards-based systems integration—a feasibility study

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ABSTRACT

Systems integration processes need to become more efficient and effective in order to allow enterprises to be nimbler and more responsive in today's dynamic markets. Systems integration typically depends on data exchange standards (DESes) and the associated DES usage specification that provides precise standard implementation requirements. However, there are significant inefficiencies in DES usage specification management today. Therefore, to achieve the objective of more responsive enterprises, DES usage specification management, particularly reuse, needs to advance. The Core Component Technical Specification carries the promise to advance the reuse by introducing the notions of Core Components (CCs), as DES building blocks, and Business Information Entities (BIEs), as DES usage specification. While the CCs idea has been successfully implemented in industry DES, the BIEs idea has been implemented only in a basic form, falling short of enabling the BIE reuse to its full potential. To realize the full potential of the BIE reuse, BIE development in industry standard usage needs to utilize the notion of business context better. In this paper, we reviewed existing business context models including UN/CEFACT Context Model (UCM), Enhanced UCM (E-UCM), and Business Context Ontology (BCOnt) and found that they were promising tools to improve the effectiveness of the BIE development and reuse. In addition to that contribution, this research took a closer look at E-UCM in particular. Two novel assessment criteria called expressiveness and effectiveness were defined. Using an industry use case and the two assessments, we showed short-comings of E-UCM such as semantic ambiguity and business rule disconnection. From there, improvements were outlined for future work to device them into E-UCM to enable a more efficient and effective BIE development and reuse process.

1. Introduction

Flexibilities are essential for enterprises to be nimbler and more responsive to changing demands and disruptions in today's dynamic markets [1–4]. To be flexible, enterprises need to be able to adapt their enterprise business processes quickly. These business processes are supported by many software applications some of which are extended into the supply chain partners [5,6]. Therefore, the ability to quickly integrate these applications and adapt them to the changing business processes contribute greatly to enterprise flexibilities. However, industrial enterprises continue to struggle with inter- and intra-organizational enterprise systems integrations which, for the sake of brevity, will be referred as systems integrations. Integration costs still steep; and its complexities prevent enterprises from achieving flexible enterprise and production processes [7]. While data exchange standards are key enablers to save integration costs and reduce its complexities [8], their outdated development and usage methods contribute greatly to challenges of standards-based systems integrations [9–11].

Data exchange standards (DESes) comprise *message schemas* and their *components*, which define valid data exchanges and allow correct data interpretation by the receiving systems. To support data exchanges for required variations in business processes, message schemas often include a very large number of components and relaxed constraints. For a particular business process, only certain components will be applicable and will have more restricted constraints on data formats, cardinalities, etc., which is captured by the *DES usage specification*.

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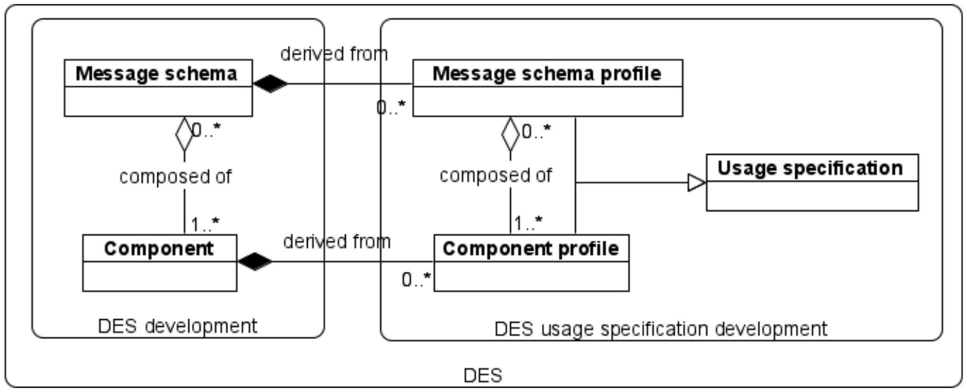

Fig. 1. The traditional framework of a data exchange standard and its usages.

Both the DES development and usage processes impact the complexities and costs of systems integration [12–14]. The *DES development* is the construction of the message schemas and their components. The *DES usage*, on the other hand, is the development of usage specification of the message schemas and their components for a specific integration use case. Result of the DES usage specification development (also called, profiling) process is *message schema profiles* and *component profiles* ready to be implemented for the integration use case whose requirements governed the profiling process. Fig. 1 illustrates these relationships among the outcomes of the DES development and the usage processes. This paper focuses on the DES usage, particularly on the message schema and component profile development and reuse.

Currently, the DES usage specification development and reuse processes are very labor-intensive, time-consuming, and costly, impacting negatively the costs and complexities of systems integrations [15]. There is virtually no support to describe, register, search for, or reason about appropriate message schema and component profiles for their reuses. To develop a DES usage specification for a specific integration use case, the process is manual and ad-hoc [16].

In this research, a new 'DES usage specification development and reuse process' (referred to as 'usage specification management', hereafter) is envisioned to be streamlined, efficient, and effective, enabling great improvements in the efficiencies and costs of systems integration. A system realizing such a process would have support to describe, register, search for, and reason about candidate message schema and component profiles based on some objective criteria for potential reuse. Such support would enable reliable, repeatable, and well-defined DES usage specification management.

The Core Component Technical Specification (CCTS) is an ISO-approved meta-model standard targeted to improve the practice of development and use of DESes [17]. CCTS carries the promise for such advancement by introducing the notions of *Core Components* (*CCs*), as DES building blocks, and *Business Information Entities* (*BIEs*), as DES usage specifications. The CCs part of CCTS has been adopted by several DESes such as OAGIS [18], UBL [19], and UN/CEFACT's Core Component Library (UN/CCL) [20], demonstrating potential for significant improvements. Most recently, the newly developed CCTS-based Score platform [21] has shown to allow the development of a new OAGIS 10.7 standard entirely using the CCTS concepts implemented in Score [22].

According to [23] context-awareness is seen as one of the most important properties in the next generation of interoperable enterprise systems. Even though CCTS adoptions, such as Score, have implemented BIE functionalities, the *Business Context* concept in the BIE has not been exploited to its full potential. According to Xu existing integration approaches "still lack formal methods that can sufficiently represent the organizational context" [24]. This shortfall limits the potential for increasing efficiency in the DES usage, especially to the benefit of message schema and component profile management. A key enabler for the Business Context-based DES usage specification management is the Business Context-aware business process model (BPM). Previously, in [25] the authors exploited the idea of Business Context-aware BPM to support the dynamic composition of business process parts. With the context-aware BPM and the envisioned usage specification management, our ultimate goal is to develop advanced Business Context-based usage specification management solution that would enable *reliable and repeatable identification of message schema and component profiles for their reuse in well-defined integration use cases.* The delivery of this missing capability is referred to as the *Central Problem* of the paper. Such new capability would pave the way for better reuse of message schema and component profiles. The envisioned approach is based on CCTS and the usage of the Business Context concept. As a path toward that goal, this paper assesses existing business context models including UN/CEFACT Context Model (UCM), Enhanced UCM (E-UCM), and Business Context Ontology (BCOnt). The finding is that they are promising tools to improve the effectiveness of the BIE development and reuse. Further investigation into E-UCM is taken using two novel assessment criteria called expressiveness and effectiveness. The definitions of these two criteria are given. Using an industry use case and the two assessments, the analysis shows short-comings of E-UCM such as semantic ambiguity and business rule disconnection. From there, the paper outlines necessary improvements for future work to device them into E-UCM to achieve the ultimate goal of advanced Business Context-based solutions. It is expected that such solutions would be able to provide a formal and well-defined DES usage specification management, with a great possibility for automation which would bring significant advancement of the effectiveness and efficiency of the standards-based integrations.

Section 2 describes related work that provides the foundation for the envisioned usage specification management and the analysis to be discussed in the rest of the paper. Section 3 describes the envisiond Business Context-based usage specification management to address the *Central Problem*. Sections 4 and 5 propose an approach to assess business context models and consequently apply it to one of the business context models, namely E-UCM. Section 6 describes the assessment results, while Section 7 identifies, based on the results, possible improvements to the E-UCM model for the future work. Finally, Section 8 closes the paper with concluding remarks.

2. Related work

2.1. Industrial information integration

Industry 4.0 envisions next phase in the evolution of manufacturing, combining advanced Internet of Things (IoT) and Cyber-Physical Systems (CPS) to facilitate a highly intelligent, interactive, and automated manufacturing ecosystems [26,27]. The authors in [28] emphasized the importance of integration for efficient smart manufacturing processes: (i) horizontal integration through value networks (inbound and outbound logistics and production), (ii) end-to-end digital integration of engineering across the entire value chain, and (iii) vertical integration and networked manufacturing systems.

Enterprise architecture (EA) is an IT methodology that supports complex integration and interoperability capability. Most EA frameworks consist of five layers—Business, Process, Integration, Software, and Technology [29]. Specifically, Integration Architecture layer is focused on achieving integration in order to support enterprise agility and efficiency. This layer identifies and represents information system components (e.g., enterprise services, application clusters, integration systems and data flows) in the corresponding enterprise context. Back in 2005, Xu proposed a conceptual framework—Industrial Information Integration Engineering (IIIE)—that provides a wholistic approach to industrial information integration [30]. Since then, the IIIE framework is established as an emerging research topic [31]. According to Chen, the framework found its application in many domains, such as aerospace, healthcare, manufacturing, supply chain, and urban development [32]. Most recently the IIIE framework was applied in the aircraft domain for aircraft coupling purposes [33], and in coal mining domain for the assessment of functional efficiency [34]. The work done in the IIIE framework to date, as shown in the references above, has not developed formal methods to take advantage of the notion of context, as commented by Xu [24]. The research results in this paper aim to provide IIIE and other frameworks with a basis that can enable such formal methods.

2.2. Context-aware systems integrations

According to Dey, et al., context can be defined as “any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves” [35]. The same authors defined context-aware system as a system that “uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task” [35]. Following the context definition provided by Dey, et al., Danijel proposed the definition of a Business Context. According to Danijel, Business Context is “any information that can be used to characterize the situation of an entity within a scope where business operates. An entity is a person, place, or object that is considered relevant to the execution of a business process in a business environment, including the business process and business environments themselves” [36].

Motta et al. in their study investigated interoperability of context-aware systems [37]. They concluded that interoperability in the context-aware systems environment is more than just exchanging and using information. In such environment, the interoperability implies inclusion of both structural and behavioral concepts. Kosek et al. studied semantic interoperability in pervasive environments and concluded that flexible and updatable standards are needed, and for that purpose context has a significant role [38]. Further, context was exploited to support semantic integration in a novel Engineering Knowledge Base (EKB) architecture that should enable integration of multidisciplinary engineering projects [39]. In [40] authors proposed the RuleXPM approach to resolve semantic interoperability problem in e-marketplace environment. In the same paper, the authors concluded that resolving semantic interoperability was important for business process integration. Context was found to be important in Industry 4.0 domains as well. Li et al. in their 5 G Internet of Things (IoT) survey envisioned context-aware IoT Middleware Solution as a promising research direction that should provide autonomous and automatic adaptation of an IoT device to any changes in context [41]. Lehmann et al. investigated application of context for smart home environment and developed a Nexus platform for context models federation [42]. Gil et al. in their work provided an extensive survey regarding the application of context in IoT applications. They concluded that context provides important support for storage, process and interpretation of big data, and for the integration of IoT and social networks [43].

2.3. DES development and DES usage

As emphasized in [44], targeted and projected integration use cases are different. The DES development process starts with a list of targeted integration use cases that are collected from the standardization organization committee members. As a result, message schemas contain a list of components with relaxed constraints to support all targeted integration use cases. On the other hand, projected integration use cases are those that were not accounted during the DES development process but there is a hope that the DES will be able to cover them as well.

Since targeted and projected integration use cases have different requirements as demonstrated in [44], customizations of the message schemas and components created from targeted use cases are necessary to address requirements of the projected integration use case at hand. This customization is known as a *DES usage specification development (profiling) process*. The DES profiling implies exclusion of irrelevant components, adjustment of component’s constraints, and, oftentimes, an addition of new components. The profiling process was performed in a manual, arbitrary, nonstandard way, without a possibility to support *reliable and repeatable identification of message schema and component profiles for their reuse in well-defined integration use cases*. Such process has a negative impact on integration and interoperability between business partners [15,16]. Traditionally, the DESes were syntax-dependent which made the profiling process even more challenging. Some of the profiling problems and challenges are discussed in [45].

2.4. Previous DES usage specification development initiatives

There were two attempts to improve the DES usage specification development. In [46], the authors used the Universal Business Language (UBL) as an exemplar DES to define the unambiguous usage specification. As emphasized earlier, UBL has already adopted CCTS in its core so, consequently, the authors proposed the approach that is based on the Business Context definition introduced in CCTS. For that purpose, they developed an ontology to represent the Business Context knowledge. That ontology comprises the knowledge collected from different taxonomies. All taxonomies are transformed into the corresponding ontology, and then alignment and reasoning techniques are performed to integrate those ontologies into one single ontology. Then, each UBL component and message schema is annotated with the ontology, which provides a basis for the message schema profiling process. The authors developed three tools to support the proposed approach including a tool that enables the inclusion of new taxonomies, a tool for component profiling purposes, and a tool for the message schema profiling process. Although this approach was promising, there are missing pieces that might have prevented it from industry adoption. First, the approach did not provide a mechanism to search for and reuse existing message schema and component profiles prior to registration of new ones. Second, since dictionary information was not considered in component profiling process, it would be possible to have same component profiles coexisting in the repository while related to different Business Context values. These two issues would have a great impact on a DES growth in a number of message schema and component profiles and on decreased reusability. Third, the message schema profiling approach assumes global applicability of component’s business context. However, the applicability of component’s business context is affected by its parent and ancestor component profiles. Therefore, such assumption can cause incorrect message schema profile.

In [47] the authors defined a framework for the standardization of governmental documents. The authors pointed out the problem with missing or uninformative usage specifications that prevent the discovery, reuse, and extension of existing components. In addition to the standardization, the framework also described an approach for usage specification development. However, the approach provided only fragmented recommendations. Consequently, it could not be a basis for streamlined, efficient, and effective DES usage specification

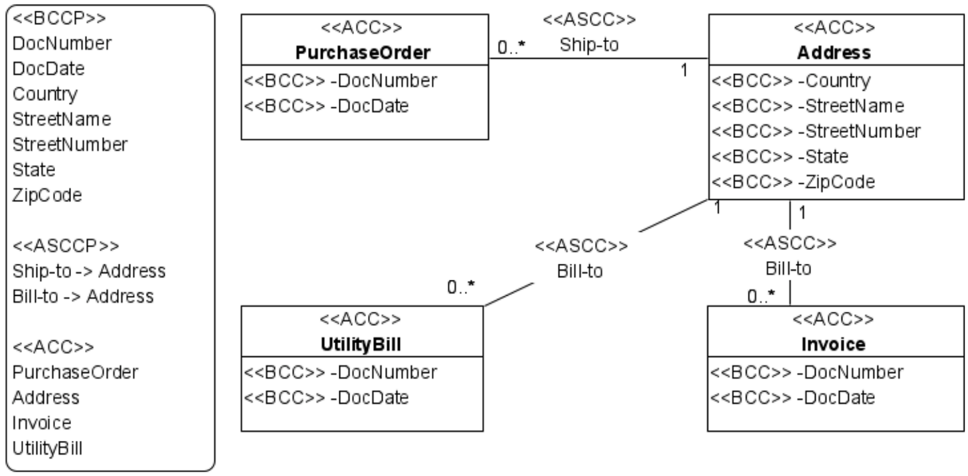

Fig. 2. A CCTS-based data exchange standard example—conceptual data model.

development.

2.5. CCTS methodology

The Core Component Technical Specification is an ISO-approved meta-model standard for the development and use of DESes [17] and one of the core technologies in data (exchange) modeling [48]. The first key notion of CCTS is CCs, which represent reusable DES building blocks. CCTS offers a set of CC types to support the CC use at different granularity levels of a DES. There are three types of CCs that can be reused: *Basic CC property (BCCP), Association CC property* (*ASCCP*) and *Aggregate CC* (*ACC*), as shown in Fig. 2. (One could say there are four reusable CC types if considering *Core Data Types* (*CDT*), but this detail is not essential for the discussion.) ACC is composed of selected BCCPs and ASCCPs. BCCP (e.g., DocNumber presented on the left side of Fig. 2) represents a small piece of information that describe an aspect of an ACC, but once it is assigned to a specific ACC (e.g., PurchaseOrder, Invoice, UtilityBill) its semantics may be specialized under that ACC. The assignment of a BCCP to an ACC is denoted as *Basic CC* (*BCC*) in CCTS (see the DocNumber BCC in the PurchaseOrder class in Fig. 2). The underlying BCCP still exists outside of the ACC and can be assigned to other ACCs. Similar idea holds for an ASCCP (e.g., Bill-To->Address presented on the left side of Fig. 2). An ASCCP is a building block that allows for one ACC to have an association to another ACC (e.g., Address) that is referred to as an associated ACC. The name of ASCCP defines a role (e.g., Bill to) that is assigned to the associated ACC. Once that ASCCP is assigned to a specific ACC (e.g., Invoice, UtilityBill) its semantics may be specialized under that ACC. An assignment of an ASCCP to an ACC is denoted as *Association CC* (*ASCC*) in CCTS (see the association between classes PurchaseOrder and Address in Fig. 2). Underlying ASCCP (Ship–To–>Address) still exists outside the PurchaseOrder and can be assigned to other ACCs. The list of BCCs and ASCCs that describe a certain ACC are denoted as *ACC Properties* (*ACCPs*). Identified CCs are represented in the form of a *conceptual data model*. Conceptual data model is independent of technology and of a specific integration use case.

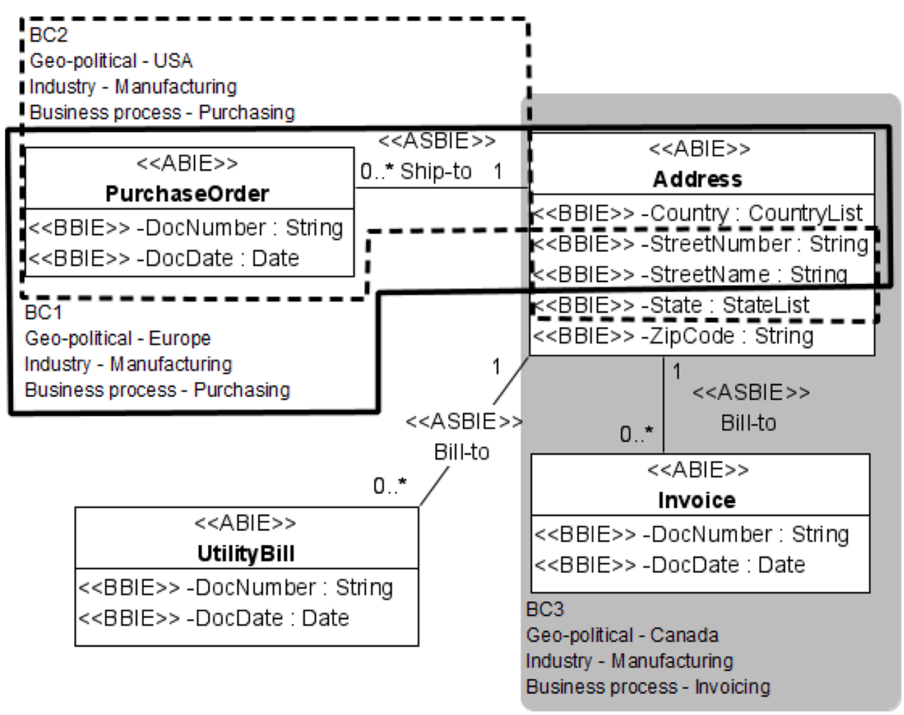

Fig. 3. A CCTS-based massage standard example—logical data model.

The second key notion of CCTS is BIEs, which represent *DES usage specifications*. In CCTS, there is a corresponding BIE (type) counterpart for each CC (type)—*BBIEP* for *BCCP, ASBIEP* for *ASCCP, ABIE* for *ACC, ABIEP* for *ACCP, BBIE* for *BCC*, and *ASBIE* for *ASCC*. The relationships between BIEs and their CC counterparts can be found in CCTS. The BIE is the result of the process where a CC is associated to a specific Business Context and its value domains are restricted. This process is called *contextualization*. Business Context is the entity used to capture the intent of BIEs providing a basis for their reuse. Associated Business Context specification identifies a class of integration use cases in which a BIE is intended to be used. Contextualization should provide a basis for more reliable *profiling* (i.e., usage specification development) processes by providing a way to identify the intent of components in specific data exchanges and, in this way, enabling their reusability in similar exchanges. Identified BIEs in the profiling are represented in the form of a *logical data model*. The logical data model is Business Context-specific, but still platform-independent. The complete list of reusable CCs and corresponding BIEs is denoted in CCTS as a *Core Components Library* (*CCL*). According to [49], BIEs needed for describing a specific data exchange (i.e., message) between two systems are denoted as *Message Information Entities* (*MIEs*).

Each CC and BIE has its detail that is described by a set of attributes. These attributes capture, for example, dictionary name, component semantic definition, data type, constraints. The complete list of these attributes can be found in CCTS. These attributes will be denoted as *CC/BIE dictionary information*. In Fig. 3, a logical data model for the previous example is presented. Let us consider the Address component. The conclusion that comes out of this example is that the Address component is applicable in Business Contexts BC1, BC2, and BC3. However, this does not hold for all of its properties. Namely, the Country BBIE is applicable in contexts BC1 and BC3, the State BBIE is applicable in contexts BC2 and BC3, the ZipCode BBIE is valid in BC3, while the StreetName and StreetNumber BBIEs are applicable in all three contexts—BC1, BC2, BC3. By associating Business Context to a component at its granularity level, one can identify a list of integration use cases in which the component is applicable and how it is applicable, establishing the basis for reusability. In the example, the Address component is reusable in different Business Contexts albeit with a different set of BBIEs. Hence, as presented in Fig. 3, the usage of a component depends on a Business Context resulting in different structures (i.e., sets of properties) necessary for exchanging the Address information in different Business Contexts.

Business Context is described with respect to a collection of Business Context categories, each describing a specific aspect of an integration use case (e.g., see BC1, BC2, BC3 in Fig. 3). CCTS proposed eight Business Context categories (e.g., business process, business process actor, geo-political, and industry), which may not be exhaustive, as one can create its own list of Business Context categories such as Business Unit when deemed necessary by, say, an enterprise integration analyst. Business Context categories have one or more associated Business Context schemes that are used as a source of possible values (e.g., [50] for geo-political Business Context category). Business Context is instantiated by composing one or more Business Context scheme values from each employed Business Context category. *Business Context knowledge base* comprises a collection of available values from each employed Business Context scheme.

2.6. Enhanced CCTS (E-CCTS) methodology

While a basis for reliable profiling processes is provided by CCTS, as discussed in Section 2.5, these processes still have to be conducted manually (e.g., an enterprise integration analyst has to interpret Business Contexts associated with BIEs in order to reuse them). In order to minimize manual profiling processes based on subjective interpretations of associated Business Contexts, E-CCTS introduces three new contextualization constructs—*Assigned, Overall* and *Effective* Business Contexts—along with its contextualization method [36].[1] Here, these contextualization constructs are summarized, while a detailed explanation is provided in Appendix A.

According to E-CCTS, contextualization includes the assignment of Business Contexts and calculation of overall and effective Business Contexts. The following describes various usages of business contexts defined in E-CCTS.

- *Assigned Business Context* (*Assigned_BC*) is a BC that is used to specify integration use cases, in which CCs are applicable. An assignment of a BC creates a BIE.
- *Overall Business Context* (*Overall_BC*) is a calculated business context. It indicates the actual BCs that the BIE can be applicable. For example, the Overall_BC of an ABIE is a union of all Overall_BCs of its components.
- *Required Business Context* (*Required_BC*) is a BC indicating an integration use case for which a BIE is needed.
- *Effective Business Context* (*Effective_BC*) is a calculated BC. It indicates which parts of a BIE are relevant to a given Required_BC.

Table 1
UCM predicates.

UCM predicate symbol	UCM predicate name	UCM predicate definition
=	Equal to	Identifies the specified node from the DAG.
!=	Not equal to	Identifies all nodes from the DAG (from the corresponding Business Context category), except the specified node.
>	Greater than	Identifies all predecessor nodes of the specified node from the DAG.
<	Less than	Identifies all successor nodes of the specified node from the DAG.
≥	Greater than or equal to	Identifies all predecessor nodes of the specified node from the DAG including the specified node itself.
≤	Less than or equal to	Identifies all successor nodes of the specified node from the DAG including the specified node itself.
~	Less than, greater than or equal to	Identifies all successor and predecessor nodes of the specified node from the DAG including the specified node itself.

2.7. Bussiness context models

This section reviews three available Business Context models. For each model, the approaches for representing Business Context knowledge and for using the knowledge to express a Business Context are discussed.

2.7.1. UCM business context model

UN/CEFACT Context Methodology (UCM) proposed a Business Context model that completely conformed to the CCTS specification [51]. Its Business Context knowledge is represented as a centralized directed acyclic graph (DAG). A node in the DAG represents a specific Business Context value, while an edge narrows the scope of the source node to the scope of the target node (e.g., America -> North America -> USA). The DAG contains a set of root nodes where each root node represents one employed Business Context scheme. Descendant nodes of a specific root node are values from the same Business Context scheme. UCM Business Context model offers a basis for definition of permissible combinations of nodes by establishing associations between nodes from

[1] While it was stated that these constructs were proposed by the UN/CEFACT, detailed analysis of the UN/CEFACT specifications has proved that any of these contextualization constructs cannot be found in the CCTS. In order to make a distinction from the available CCTS specification [17] the content that was presented in [36] as CCTS is denoted as Enhanced CCTS (E-CCTS).

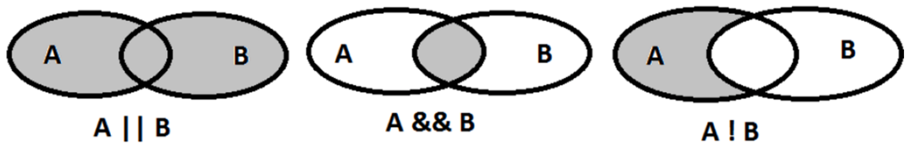

Fig. 4. UCM operators.

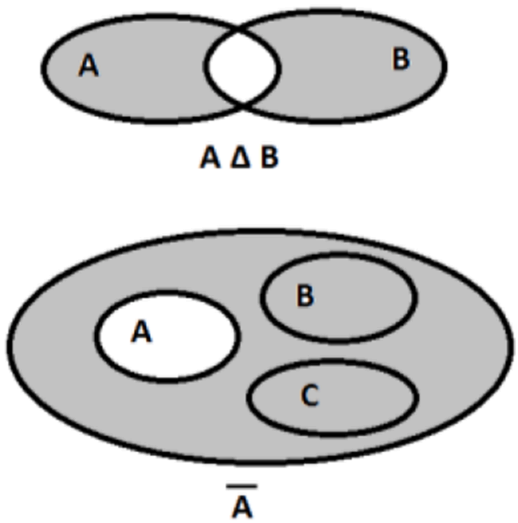

Fig. 5. Additional E-UCM operators.

the same or from different Business Context schemes [52]. These permissible associations are driven by a specific use that brings additional enrichment of the Business Context knowledge base (with additional semantics). This is achieved by adding new associations between nodes from the same, or from different schemes. These associations, called context paths, reflect the domain-specific business rules. In [52], a context path is defined as a sequence of graph nodes that represent a specific semantic meaning. The complete UCM Business Context graph metamodel was documented in [51].

In UCM, each *Business Context expression* consists of one simple or compound Business Context clause. If the clause is simple, then it consists of one predicate associated with a single node. The UCM provides seven available predicates as presented in Table 1.

A compound clause consists of two ordered simple or compound clauses that are connected using one of the three UCM operators—union (||), intersection (&&), or exclusion (!). The UCM operators are developed according to the Set Theory. The results of all UCM operators are presented as gray parts in Fig. 4.

For each employed Business Context category one such clause should be constructed. In other words, a Business Context expression is a union of all clauses (simple or compound) for each Business Context category. When a Business Context expression is resolved with a Business Context knowledge base, the result is a union of nodes resolved for each Business Context category.

2.7.2. E-UCM business context model

Novakovic and Huemer [53] introduced E-UCM model. E-UCM is an approach for representing Business Context knowledge and use it to express Business Context. It completely conforms to the E-CCTS specification. The model assumes that the Business Context knowledge base is complete and consistent. E-UCM Business Context model represents Business Context knowledge in the form of a decentralized graph where each subgraph represents only Business Context knowledge that is relevant to a considered business process. This enhancement was important because it sped up the Business Context graph traversal and

Table 2
BCOnt predicates.

BCOnt predicate symbol	BCOnt predicate name	BCOnt predicate definition
$\equiv$	Equivalent to	Identifies the specified individual from the BCOnt
$!\equiv$	Not equivalent to	Identifies all individuals from the BCOnt that belong to the same Business Context category as specified individual, except the specified individual
$\sqsupset$	Superset of	Identifies individuals from the BCOnt that are associated to the specified individual along the superclass-subclass properties
$\sqsubset$	Subset of	Identifies individuals from the BCOnt that are associated to the specified individual along the subclass-superclass properties
$\sqsupseteq$	Superset of or equivalent to	Identifies individuals from the BCOnt that are associated to the specified individual along the superclass-subclass properties including the specified individual
$\sqsubseteq$	Subset of or equivalent to	Identifies individuals from the BCOnt that are associated to the specified individual along the subclass-superclass properties including the specified individual
$\sqsupseteq\sqsubseteq$	Subset of, superset of or equivalent to	Identifies individuals from the BCOnt that are associated to the specified individual along the subclass-superclass and superclass-subclass properties including the specified individual

improved the maintainability of the graph. The second enhancement was the introduction of the restriction weight measure. It denotes the shortest distance between two graph nodes (number of edges that have to be traversed).

For the construction of a Business Context expression, E-UCM adopted the UCM operators (see Fig. 4) and predicates (see Table 1) and introduced two additional operators—symmetric exclusion ($\triangle$) and complement (i.e., $\overline{A}$ where A is a clause). The results of additional E-UCM operators are presented as gray parts in Fig. 5.

These enhancements have increased the Business Context expressiveness. All the E-UCM operators, including the symmetric exclusion, are binary, while the complement is the only unary operator.

2.7.3. BCOnt business context model

Business Context Ontology (BCOnt) is another Business Context model. It relies on ontology web language standard - OWL [54]. The approach completely conforms to the E-CCTS specification. Its Business Context knowledge is implemented as a three-level ontology. The top-level describes general concepts of Business Context (e.g., Business Context categories). The middle level consists of different subontologies each of which captures knowledge about a specific Business Context category (e.g., BCISIC subontology created for *Industry* Business Context category, based on [55]). The lowest level contains a list of subontologies that refine general concepts introduced by the upper levels.

Business Context values are represented as OWL individuals. The hasMember (or its inverse memberOf) OWL property is used to establish

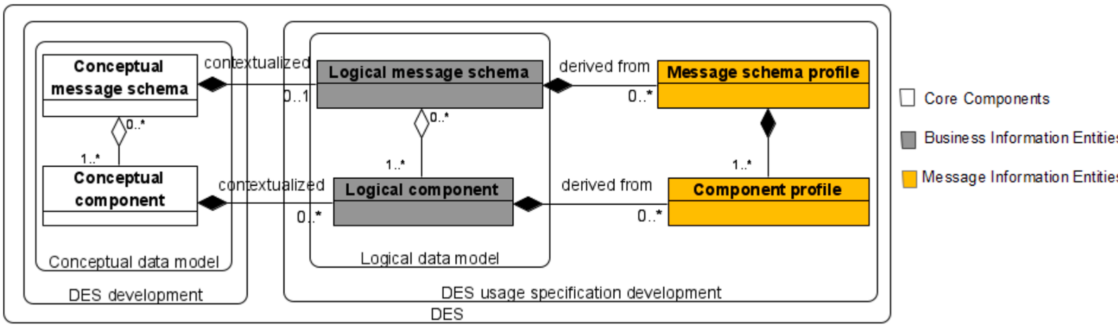

Fig. 6. The structure of data exchange standard—a new approach.

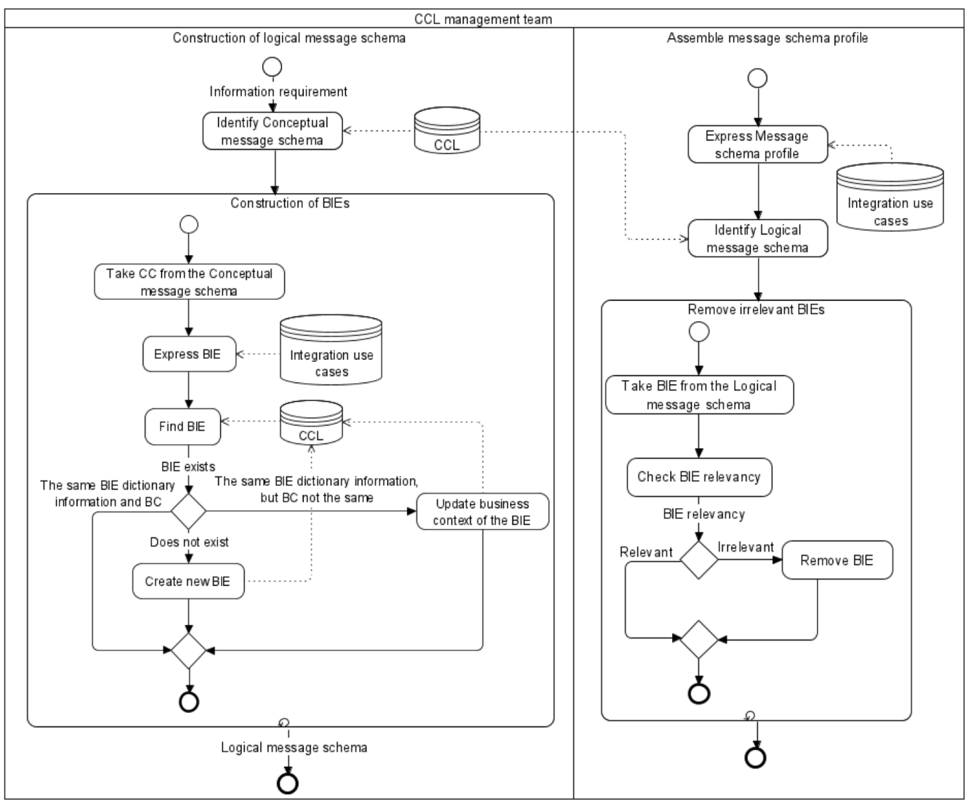

Fig. 7. A Business Context-based DES usage specification management.

the superclass-subclass (or subclass-superclass) relationships between these individuals as a DAG.

The main advantage of this context model is the possibility to extend the knowledge base with external ontologies in order to define potentially missing concepts. BCOnt also employs restriction weight measure that was previously mentioned in the E-UCM.

The BCOnt uses Description Logic (DL) syntax to form a Business Context expression. Each expression consists of one clause, which can be simple or compound. If the clause is simple, then it consists of a predicate associated with a single individual. BCOnt provides a list of seven available predicates as presented in Table 2.

A compound clause consists of two ordered simple or compound clauses that are connected using one of the four provided binary operators—union ($\sqcup$), intersection ($\sqcap$), exclusion (!!), or symmetric exclusion ($\triangle$). Also, a compound clause can consist only of one simple or compound clause in a combination with the unary operator—complement ($\neg$). The meanings of BCOnt operators are the same as previously defined by UCM and E-UCM (see Fig. 4 and Fig. 5).

Although all three business context models above are promising for the envisioned Business Context-based DES usage specification management, this paper focuses on a detail assessment of E-UCM as it is an enhancement of UCM. Assessment of BCOnt is left as future work.

3. Business context-based DES usage specification management

This section outlines a new framework for the DES usage specification management (development and reuse) process. The envisioned framework is different from that of the traditional one presented in Fig. 1. Fig. 6 shows additional notions that differentiate the conceptual, logical, and concrete artifacts in the DES as follows.

Definition 1: *Conceptual data model is a data model that contains all Core Components needed to describe any business document type within any domain.*

Definition 2: *Conceptual message schema contains a subset of Core Components (conceptual components) from the conceptual data model needed to describe a certain business document type.*

Definition 3: *Logical data model is a data model that contains all Business Information Entities, created from Core Components in the*

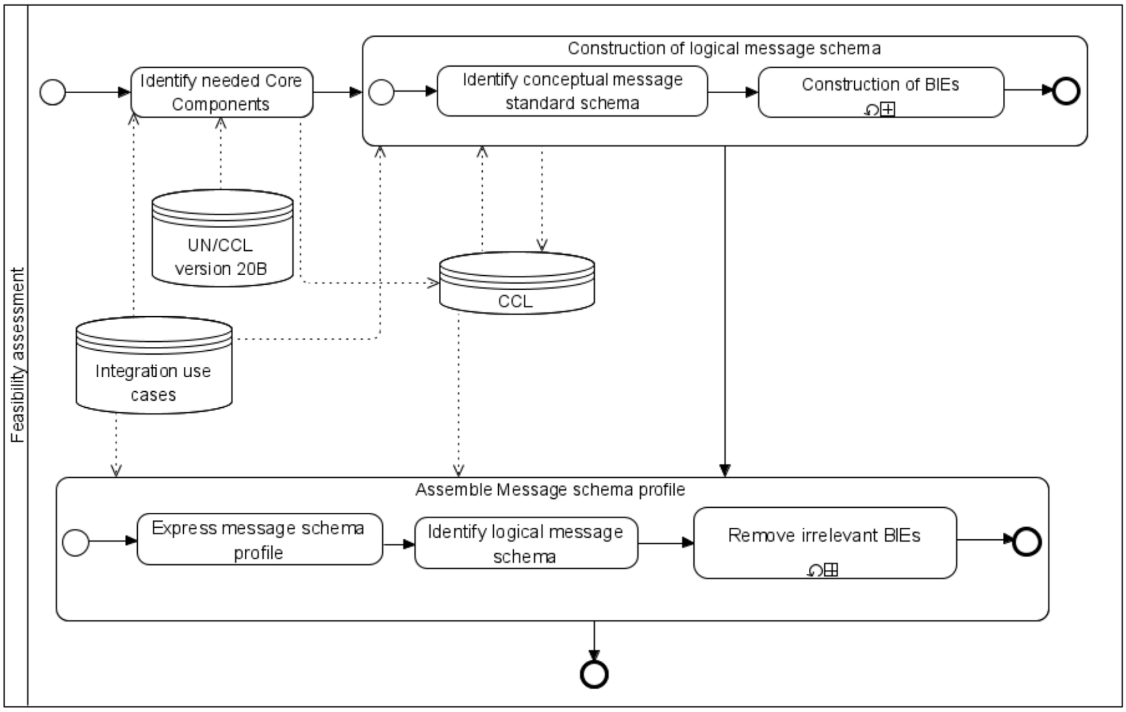

Fig. 8. Feasibility assessment process steps.

conceptual data model, needed to describe any business document type in any known integration use case within a certain domain.

Definition 4: *Logical message schema contains a subset of Business Information Entities (logical components) from the logical data model needed to describe a certain business document type in all known integration use cases.*

Definition 5: *Message schema profile contains a subset of Business Information Entities from the corresponding logical message schema, needed to describe a business document type for a specific integration use case. This is a concrete artifact used in integration (albeit still execution platform-neutral).*

The envisioned DES usage specification management process is presented in Fig. 7. Two workflows are needed to support the new process (each of them is shown as a separate swimlane) and they are described in Sections 3.1 and 3.2. For the scope of this paper that focuses on the DES usage phase and not the DES development, the conceptual data model and conceptual message schemas are assumed to be readily available.

3.1. Construction of the logical message schema

The objective of this workflow is to construct the logical message schema (BIEs) from the conceptual message schemas and their components (CCs). It starts from the integration analyst analyzing a business process model that describes an integration domain and identifying integration points (i.e., message flows that need to be exchanged among applications or business partners). When an appropriate conceptual message schema is identified, the integration analyst retrieves the complete list of CCs that describe the structure of that schema from the CCL. Further, in order to contextualize CCs, the integration analyst associates each CC with the corresponding dictionary information and the Business Context that describe the target integration use case (the *Express BIE* activity). The next task for the integration analyst is to search the CCL in order to check whether the same (or similar) BIEs already exist. This step is a crucial enhancement in this new process because it would increase the reusability of existing BIEs. The CCL is searched using two criteria—dictionary information and Business Context of the BIE constructed for the observed integration use case. There are three possible outcomes:

1. There is an existing BIE with the same dictionary information, but with the Business Context that does not cover the observed integration use case. In this case, there is no need to create a duplicated BIE, only its Business Context needs to be updated in order to include the newly identified integration use case.
2. There is no existing BIE with the same dictionary information, so a new BIE has to be created.
3. There is an existing BIE with the same dictionary information and the Business Context that covers the observed integration use case. In that case, there is no need to make any changes to the CCL.

In this workflow, the corresponding conceptual message schema might not contain all CCs needed for the desired integration use case. In that case, the integration analyst should create new CCs. However, this situation is out of scope, since the paper covers the DES usage, and not the DES development process. The output of this workflow is the logical message schema that contains all BIEs for the target integration use case.

3.2. Assemble message schema profile

In the second workflow, the integration analyst uses previously created BIEs to assemble a message schema profile needed for the data exchange in a message flow of a specific integration use case. The first task for the integration analyst is to define a Required_BC for the interested message flow (the *Express message schema profile* activity). The integration analyst identifies a logical message schema(s) from the CCL that should be profiled. In order to assemble the message schema profile, the integration analyst takes each BIE found in the corresponding logical message schema and checks BIE's relevancy for the Required_BC. At that point, all irrelevant BIEs should be removed.

4. Feasibility assessment plan

This section describes the plan to assess how E-UCM may support to the envisioned DES usage specification management approach outlined

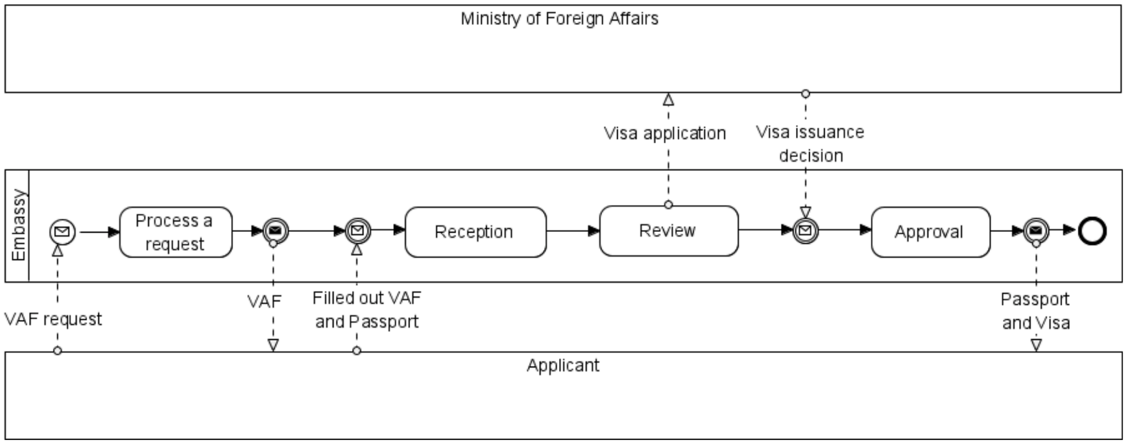

Fig. 9. Travel visa application business process.

in Section 3. Then, Section 5 and 6 will, respectively, discuss the assessment and the assessment results.

4.1. Assessment process

Two measures, namely Expressiveness and Effectiveness, are proposed to assess business context models as described below. Consequently, E-UCM is assessed as such. as follows:

- Expressiveness: Do Business Context expressions have the ability to express intended use for all real integration use case specificities? This measure refers to the business context model capability to adequately support *Express message schema profile* and *Express BIE* activities in the envisioned Business Context-based approach for DES usage specification management (see Fig. 7).
- Effectiveness: Can the Business Context expressions be used as a basis for message schema and component profiles management? This measure refers to the business context model capability to adequately support *Find BIE, Check BIE relevancy*, and *Identify logical message schema* activities in the envisioned usage specification management.

The feasibility assessment uses the two measures in a three-step process outlined in Fig. 8. The first step is a preparation step. It identifies needed CCs from the existing Core Components Library [20]. The second step is the construction of the logical message schema. Finally, the third step is to assemble the message schema profile. Together the 2^{nd} and 3^{rd} steps evaluate the business context model, and E-UCM in particular, against the two measures.

4.2. Assessment domain

In this paper, the feasibility assessment will be conducted for the travel visa application domain in the tourism industry. The travel visa application domain was chosen for two reasons: (1) domain rules could be extracted from forms freely available online; and (2) domain rules are broadly understood by the public. In Fig. 9, a Business Process Model and Notation (BPMN) diagram of a simplified travel visa application process is presented. For simplicity, an assumption is made, without affecting the integrity of the assessment, that the business process is the same for each considered issuance country as follows.

There are three identified parties that exchange messages—Applicant, Embassy, and Ministry of Foreign Affairs. The process starts when an Applicant sends a Visa Application Form (VAF) request. The Embassy processes the request and sends VAF back to the Applicant. The next step is the reception of a completed VAF and the applicant's Passport. The received documents are reviewed and the Visa application (where all necessary information from the applicant's VAF and the passport are extracted) is sent to the Ministry of foreign affairs for a decision. The final step is the approval step. In this step, upon received Visa issuance decision from the Ministry of foreign affairs the Passport is sent back to the Applicant, if approved with a Visa, otherwise without one.

Table 3
Business Context categories and assigned schemes..

Business Context category	Business Context schemes
Issuance country	Countries
Applicant's country	Countries
Business Process	Travel visa application process
Visa type	Visa type list

4.3. Integration use cases

For this assessment, the Integration use cases repository (in Fig. 8) is assumed to have a set of VAFs that are obtained from the corresponding websites, which were selected because of their accessibility and quality of description [56–59]. The analysis will focus on the following subset of integration use cases:

1 VAF of South Korea (single VAF is used for all visa types)
2 VAF of Thailand (single VAF is used for all visa types)
3 VAF of Ireland for temporary worker visa type
4 VAF of Ireland for tourist visa type

4.4. Business context knowledge base

Four Business Context categories will be employed in the Business Context knowledge base to describe Business Contexts in this feasibility assessment. They take values from three Business Context schemes as outlined in Table 3.

Fig. 10 shows a portion of the employed schemes associated with the Business Context categories. For the Visa type Business Context category, a taxonomy of common visa types from a reference is used [60]. In this taxonomy, there are five subcategories, namely transit, short-stay, long-stay, immigrant and official, each of which is further subdivided into visa sub-types. In reality, each country has a specific list of visa types, but these specificities are neglected for the sake of clarity.

Travel visa application process scheme is used to represent the hierarchy of identified sub-processes. The hierarchy is corresponding to the business process in Fig. 9. Sub-nodes are activities while leaf nodes are message that are exchanged between business partners.

As stated in Section 2.7.1, domain-specific business rules can bring

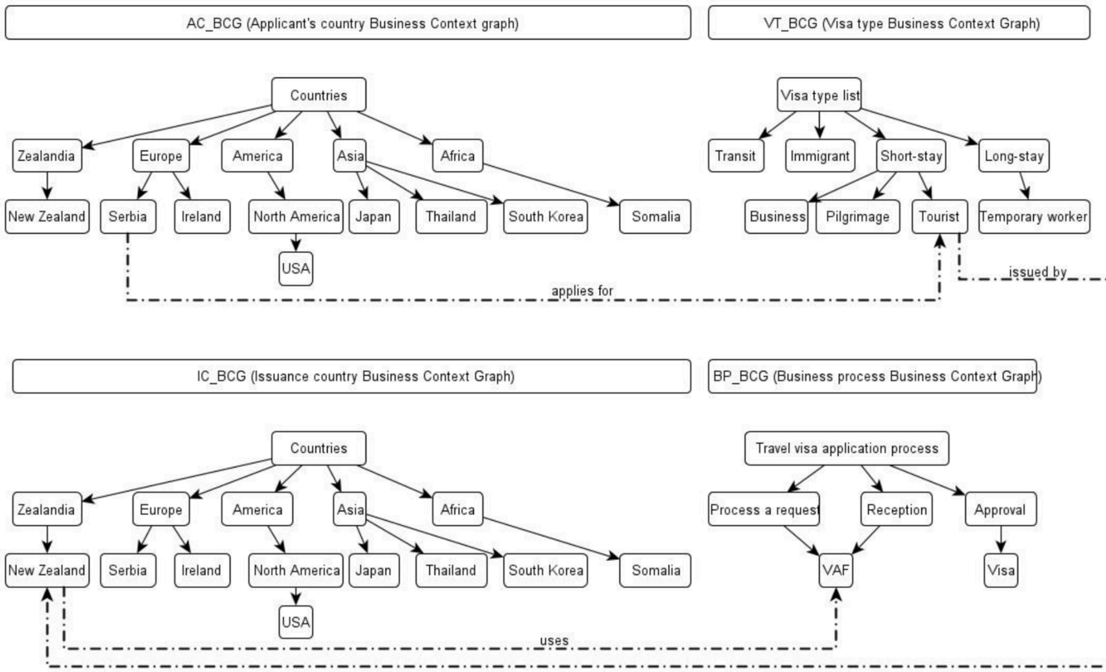

Fig. 10. Business Context knowledge base—an excerpt.

Table 4
Business Context knowledge base - domain-specific business rules.

Rule number	Rule
R1	Serbian(x) & TempWorker(y) & appliesFor (x, y) & issuedBy (y, New Zealand) -> Use (x, VAF)
R2	Serbian(x) & Tourist(y) & appliesFor (x, y) & issuedBy (y, New Zealand) -> Use (x, VAF)
R3	Irish(x) & BusinessVisa(y) & appliesFor (x, y) & issuedBy (y, New Zealand) -> Use (x, VAF)
R4	African(x) & Tourist(y) & appliesFor (x, y) & issuedBy (y, South Korea) -> Use (x, VAF)
R5	African(x) & BusinessVisa(y) & appliesFor (x, y) & issuedBy (y, South Korea) -> Use (x, VAF)
R6	European(x) & TempWorker(y) & appliesFor (x, y) & issuedBy (y, South Korea) -> Use (x, VAF)
R7	European(x) & Tourist(y) & appliesFor (x, y) & issuedBy (y, South Korea) -> Use (x, VAF)

additional semantics to the Business Context graph. In the travel visa application domain, a common rule pattern is as follows: *An applicant coming from Applicant country A can* ***apply for*** *Visa type B if it is* ***issued by*** *Issuance country C, and for that purpose the Issuance country C* ***uses*** *document D*. Such kind of domain-specific business rule reveals possible visa applications, or possible context paths. Three domain-specific relationships are defined for encoding such rules: "issued by" and "applies for" and "uses". Table 4 shows some rules drawn from the [61] encoded using those relationships. R2 is shown in Fig. 10 as a context path.

5. Assessment

This section walks through the analysis of each step in the planned assessment process described in the previous section. First, the integration analyst has to analyze a collection of integration use cases in order to identify needed CCs. The result of this step is a collection of conceptual message schemas that make up the conceptual data model. Then in the *Construction of Logical Message schema* step, these conceptual message schemas are contextualized by the means of E-UCM. The result is the logical message schemas that make up the logical data model. Finally, appropriate logical message schemas are profiled for each desired integration use case listed in Section 4.3. As a result, four message schema profiles are assembled.

5.1. Core components selection

By inspecting the obtained integration use cases the integration analyst has identified the needed CCs from the existing CCL [20]. A portion of the conceptual data model is presented in Fig. 11. Since there is only one conceptual message schema—VAF—there is no difference between its structure and the conceptual data model. In general, as stated in Section 3, the conceptual data model would comprise the whole set of CCs identified in any of conceptual message schemas. In Fig. 11, three ACCs from the conceptual data model are shown. They are described with corresponding BCCs and ASCCs.

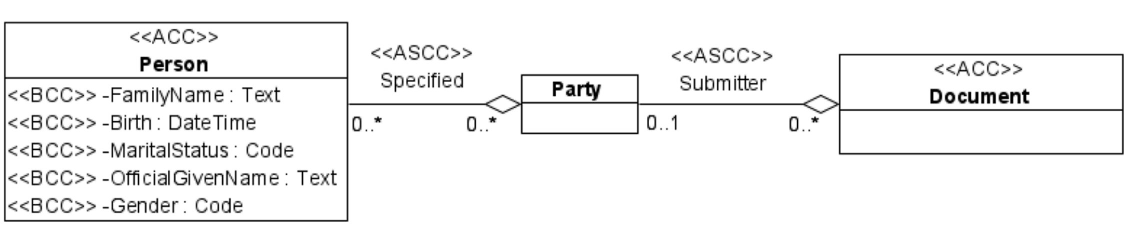

Fig. 11. A portion of the conceptual data model.

Table 5
ABIEP contextualization.

<table>
<tr><th>ABIEP type</th><th>ID</th><th colspan="2">ABIEP dictionary information</th><th>ABIEP's Assigned_BC</th></tr>
<tr><td>BBIE</td><td>PFN</td><td>Person. Family name</td><td></td><td>((<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Thailand)) || (=VAF)) || ((<AC_BCG_Countries) || ((=Temporary worker) || (=Tourist)) || (=IC_BCG_Ireland) || (=VAF))</td></tr>
<tr><td></td><td>PB1</td><td>Person. Birth</td><td>YYYY-MM-DD</td><td>(<AC_BCG_Countries) || (<Visa type list) || (=IC_BCG_South Korea) || (=VAF))</td></tr>
<tr><td></td><td>PB2</td><td>Person. Birth</td><td>DD-MM-YYYY</td><td>(<AC_BCG_Countries) || (=Tourist)) || (=IC_BCG_Ireland) || (=VAF)</td></tr>
<tr><td></td><td>PB3</td><td>Person. Birth</td><td></td><td>((<AC_BCG_Countries) || (=Temporary worker) || (=IC_BCG_Ireland) || (=VAF)) || ((<AC_BCG_Countries) || (<Visa type list) || (=IC_BCG_Thailand)) || (=VAF))</td></tr>
<tr><td></td><td>PM1</td><td>Person. Marital status</td><td>Married, Divorced, Single</td><td>(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=VAF))</td></tr>
<tr><td></td><td>PM2</td><td>Person. Marital status</td><td></td><td>(<AC_BCG_Countries) || (<Visa type list) || (=IC_BCG_Thailand) || (=VAF))</td></tr>
<tr><td></td><td>PM3</td><td>Person. Marital status</td><td>Single, Married, Widowed, Divorced, Separated</td><td>(<AC_BCG_Countries) || (=Tourist) || (=IC_BCG_Ireland) || (=VAF)</td></tr>
<tr><td></td><td>PON</td><td>Person. Official given name</td><td>In Kanji</td><td>((=AC_BCG_China) || (=AC_BCG_Japan)) || (<Visa type list) || (=IC_BCG_South Korea) || (=VAF)</td></tr>
<tr><td></td><td>PG</td><td>Person. Gender</td><td>Female, Male</td><td>((<AC_BCG_Countries) || (<Visa type list) || (=IC_BCG_South Korea)) || (=VAF)) || ((<AC_BCG_Countries) || (=Tourist) || (=IC_BCG_Ireland) || (=VAF))</td></tr>
<tr><td>ASBIE</td><td>DSP</td><td>Document. Submitter. Party</td><td></td><td>((<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Thailand)) || (=VAF)) || ((<AC_BCG_Countries) || ((=Temporary worker) || (=Tourist)) || (=IC_BCG_Ireland) || (=VAF))</td></tr>
<tr><td></td><td>PSP</td><td>Party. Specified. Person</td><td></td><td>((<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Thailand)) || (=VAF)) || ((<AC_BCG_Countries) || ((=Temporary worker) || (=Tourist)) || (=IC_BCG_Ireland) || (=VAF))</td></tr>
</table>

Note: AC_BCG refers to Applicant's country Business Context graph (see Fig. 10).

Table 6
ABIEP contextualization—after application of associative property.

<table>
<tr><th>ABIEP type</th><th>ID</th><th colspan="2">ABIEP dictionary information</th><th>ABIEP's Assigned_BC</th></tr>
<tr><td>BBIE</td><td>PFN</td><td>Person. Family name</td><td></td><td>(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Thailand) || (=IC_BCG_Ireland)) || (=VAF))</td></tr>
<tr><td></td><td>PB1</td><td>Person. Birth</td><td>YYYY-MM-DD</td><td>(<AC_BCG_Countries) || (<Visa type list) || (=IC_BCG_South Korea) || (=VAF)</td></tr>
<tr><td></td><td>PB2</td><td>Person. Birth</td><td>DD-MM-YYYY</td><td>(<AC_BCG_Countries) || (=Tourist)) || ((=IC_BCG_Ireland)) || (=VAF)</td></tr>
<tr><td></td><td>PB3</td><td>Person. Birth</td><td></td><td>(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_Thailand) || (=IC_BCG_Ireland) || (=VAF)</td></tr>
<tr><td></td><td>PM1</td><td>Person. Marital status</td><td>Married, Divorced, Single</td><td>(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=VAF)</td></tr>
<tr><td></td><td>PM2</td><td>Person. Marital status</td><td></td><td>(<AC_BCG_Countries) || (<Visa type list) || (=IC_BCG_Thailand) || (=VAF)</td></tr>
<tr><td></td><td>PM3</td><td>Person. Marital status</td><td>Single, Married, Widowed, Divorced, Separated</td><td>(<AC_BCG_Countries) || (=Tourist) || (=IC_BCG_Ireland) || (=VAF)</td></tr>
<tr><td></td><td>PON</td><td>Person. Official given name</td><td>In Kanji</td><td>((=AC_BCG_China) || (=AC_BCG_Japan)) || (<Visa type list) || (=IC_BCG_South Korea) || (=VAF)</td></tr>
<tr><td></td><td>PG</td><td>Person. Gender</td><td>Female, Male</td><td>(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Ireland)) || (=VAF)</td></tr>
<tr><td>ASBIE</td><td>DSP</td><td>Document. Submitter. Party</td><td></td><td>(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Thailand) || (=IC_BCG_Ireland)) || (=VAF))</td></tr>
<tr><td></td><td>PSP</td><td>Party. Specified. Person</td><td></td><td>(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Thailand) || (=IC_BCG_Ireland)) || (=VAF))</td></tr>
</table>

5.2. Construction of logical message schema

The next step in front of the integration analyst was to construct logical message schemas following the workflow in the *Construction of logical message schema* swimlane presented in Fig. 7. This step was conducted in one single iteration, which means that all integration use cases are considered at once. As stated previously, Business Context was described using four chosen categories—Issuance country, Visa type, Applicant country and Business process. Accordingly, Business Context expressions are defined in the following form:

(Applicant's country Business Context clause) || (Visa type Business Context clause) || (Issuance country Business Context clause) || (Business Process Business Context clause)

First, the integration analyst had to *Identify conceptual message schema* (see Fig. 7). Next, he used the target integration use cases to contextualize the VAF conceptual message schema.

For each CC found in the conceptual message schema, the integration analyst had to *Express BIE* (see Fig. 7). The ABIEP dictionary information was recognized from the corresponding integration use case, while its Business Context expression was constructed by answering the following questions:

Table 7
ABIE and ASBIE contextualization.

BIE type	ID	BIE dictionary information	BIE's Overall_BC
ABIE	P1	Person	(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Thailand) || (=IC_BCG_Ireland)) || (=VAF)
	D1	Document	(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Thailand) || (=IC_BCG_Ireland)) || (=VAF)
	PA1	Party	(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Thailand) || (=IC_BCG_Ireland)) || (=VAF)
ASBIE	DSP	Document. Submitter. Party	(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Thailand) || (=IC_BCG_Ireland)) || (=VAF)
	PSP	Party. Specified. Person	(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Thailand) || (=IC_BCG_Ireland)) || (=VAF)

Table 8
Message schema profiles' contextualization.

MP	Message schema profile name	Message schema profile's Required_BC
MP1	VAF_South Korea	(<AC_BCG_Countries) || (<Visa type list) || (=IC_BCG_South Korea) || (=VAF)
MP2	VAF_Ireland – Tourist	(<AC_BCG_Countries) || (=Tourist) || (=IC_BCG_Ireland) || (=VAF)
MP3	VAF_Ireland – Temporary worker	(<AC_BCG_Countries) || (=Temporary worker) || (=IC_BCG_Ireland) || (=VAF)
MP4	VAF_Thailand	(<AC_BCG_Countries) || (<Visa type list) || (=IC_BCG_Thailand) || (=VAF)

1 For which applicants' countries is it valid?
2 For which issuance countries is it valid?
3 For which visa types is it valid?
4 In which document type does it appear?

Further, the integration analyst had to search the CCL in order to *Find BIE* with the same dictionary information (and Business Context). However, he did not have any means to perform a dictionary information-based search, so each expressed ABIEP was inserted into the CCL. A portion of inserted ABIEPs drawn from [56–59] is presented in Table 5.

Let us further analyze Business Context expression associated with *Person. Family name* BBIE. Due to the associative property of a union operator, the mentioned Business Context expression can be reduced to:

((<AC_BCG_Countries) || (<AC_BCG_Countries)) || ((<Visa type list) || (=Temporary worker) || (=Tourist)) || ((=IC_BCG_South Korea) || (=IC_BCG_Thailand) || (=IC_BCG_Ireland)) || ((=VAF) || (=VAF))

And further to:

(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Thailand) || (=IC_BCG_Ireland)) || (=VAF)

After applying the associative property of a union operator, ABIEPs' contextualization can be reduced as presented in Table 6.

The same steps were conducted for each ABIE. ABIEs are expressed with dictionary information that was recognized from the corresponding integration use case, while their Overall_BC is calculated by applying rules summarized in Section 2.6 and detailed in Appendix A. In Table 7, the Overall_BCs for ABIEs and ASBIEs are presented.

5.3. Assemble message schema profile

The next step was to assemble message schema profiles for each interested integration use case. As a result, four message schema profiles are created. This task is conducted with respect to the business process in the *Assemble message schema profile* swimlane presented in Fig. 7. The process is repeated for each integration use case. The first task for the integration analyst was to *Express message schema profiles* (see Fig. 7). Required_BCs for the interested message schema profiles are presented in Table 8. For example, the Required_BC expression assigned to *VAF_Ireland – Temporary worker* message schema profile means that it is valid for applicants, coming from any country in the world, who apply for the Irish Temporary worker visa.

The next step was to *Identify logical message schema*. For that purpose, the integration analyst used a part of the Business Context expression that describes the Business Process category (see the Business Context expression form in Section 5.2). In this analysis, the logical message schema is the VAF logical message schema, i.e., all of the message schema profiles would refine the VAF logical message schema.

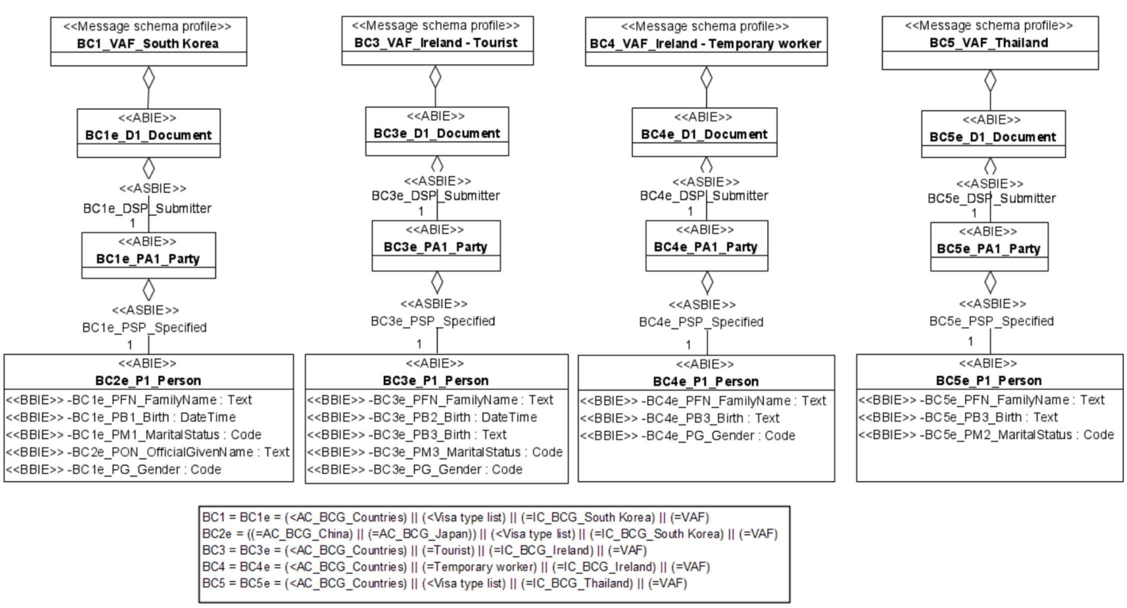

Fig. 12. Assembled Message schema profiles.

Table 9
BBIE *Person. Gender* - A portion of integration use cases.

<table>
<tr><th>Number</th><th>Integration use case</th></tr>
<tr><td>1</td><td>(=AC_BCG_Africa) || (=BusinessVisa) || (=IC_BCG_South Korea) || (=VAF)</td></tr>
<tr><td>2</td><td>(=AC_BCG_Serbia) || (=Tourist) || (=IC_BCG_South Korea) || (=VAF)</td></tr>
<tr><td>3</td><td>(=AC_BCG_Germany) || (=Temporary worker) || (=IC_BCG_South Korea) || (=VAF)</td></tr>
<tr><td>4</td><td>(=AC_BCG_Africa) || (=Pilgrimage) || (=IC_BCG_South Korea) || (=VAF)</td></tr>
</table>

The next step was to *Remove irrelevant BIEs*. For each BIE from the corresponding logical message schema, the integration analyst checked the BIE's relevancy by calculating its Effective_BC (see *Effective part of message schema* in Appendix A). All BIEs that had Effective_BC equal to null were treated as irrelevant and filtered out from the logical message schema. In Fig. 12, all assembled message schema profiles are presented.

For example, BC$_{1e}$ is the Effective_BC for the *Person. Family name* BBIE. (Even though in most of these examples, BIEs within the same message schema profile have the same Effective_BC, it does not necessarily happen in general case.)

6. Assessment results

This section presents the results of the feasibility assessment process regarding the E-UCM expressiveness and effectiveness.

6.1. E-UCM expressiveness

As stated previously, due to the associative property of a union operator, Business Context expressions are reduced as presented in Table 6. But let us consider a BBIE, *Person. Gender*, before the associative property was applied. According to its Assigned_BC *(*see Table 5), the BBIE is valid in all visa types' VAF in South Korea but only for tourist visa type in Ireland. After the associative property has been applied, observed Business Context expression was reduced to:

Example 1: (<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Ireland)) || (=VAF)

The result is not correct since it now means that BBIE *Person. Gender* is applicable for all visa types issued by Ireland. The same happened with BBIE *Person. Birth* (see BBIE *Person. Birth* with ID='PB3' in Table 5). As it can be seen, the meaning changes when the associative property of a union operator has been applied. This brings us to the conclusion that there are semantic issues with the Business Context expressions and their operators as it can lead to unintended results (***Semantics issue***).

As stated in Section 2.7.1, the Business Context expression presented in *Example 1* identifies a list of integration use cases in which the BBIE *Person. Gender* is valid, while each integration use case is described by a unique combination of values resolved for each Business Context category. A portion of possible integration use cases is presented in Table 9.

By analyzing the business rules presented in Table 4, the conclusion is that the 4th integration use case is not valid because the Pilgrimage visa type is not supported in South Korea. The conclusion is that the Business Context expressions do not consider business rules (i.e., additional context paths) that exist in the Business Context knowledge base (***Business-rule-violation issue***).

6.2. E-UCM effectiveness

During the construction of Logical message schemas, the integration analyst has faced with the fact that E-UCM describes a method for contextualization with the 'complete' assumption. Under such assumption, all integration use cases, in which components are valid, are accounted for in the knowledge base (i.e., there are no future anticipated updates of a BIE's Business Context), thus eliminating a possibility for reuse of existing components in a new integration use case and the component's Business Context update. In the case study presented in this paper, this was not a problem since all integration use cases were assumed to be accounted for, but it would become a serious problem if the integration analyst would want to update the logical data model with a newly identified integration use case that was not considered before.

Table 10
BBIE contextualization—after new integration use case.

<table>
<tr><th>ABIEP type</th><th>ID</th><th>ABIEP dictionary information</th><th></th><th>ABIEP's Assigned_BC</th></tr>
<tr><td>BBIE</td><td>PFN</td><td>Person. Family name</td><td></td><td>(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Thailand) || (=IC_BCG_Ireland)) || (=VAF)</td></tr>
<tr><td></td><td>PFN2</td><td>Person. Family name</td><td></td><td>(<AC_BCG_Countries) || (=Tourist) || (=IC_BCG_New Zealand) || (=VAF)</td></tr>
<tr><td></td><td>PB1</td><td>Person. Birth</td><td>YYYY-MM-DD</td><td>(<AC_BCG_Countries) || (<Visa type list) || (=IC_BCG_South Korea) || (=VAF)</td></tr>
<tr><td></td><td>PB2</td><td>Person. Birth</td><td>DD-MM-YYYY</td><td>(<AC_BCG_Countries) || (=Tourist)) || ((=IC_BCG_Ireland)) || (=VAF)</td></tr>
<tr><td></td><td>PB4</td><td>Person. Birth</td><td>DD-MM-YYYY</td><td>(<AC_BCG_Countries) || (=Tourist) || (=IC_BCG_New Zealand) || (=VAF)</td></tr>
<tr><td></td><td>PB3</td><td>Person. Birth</td><td></td><td>(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_Thailand) || (=IC_BCG_Ireland) || (=VAF)</td></tr>
<tr><td></td><td>PM1</td><td>Person. Marital status</td><td>Married, Divorced, Single</td><td>(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=VAF)</td></tr>
<tr><td></td><td>PM2</td><td>Person. Marital status</td><td></td><td>(<AC_BCG_Countries) || (<Visa type list) || (=IC_BCG_Thailand) || (=VAF)</td></tr>
<tr><td></td><td>PM3</td><td>Person. Marital status</td><td>Single, Married, Widowed, Divorced, Separated</td><td>(<AC_BCG_Countries) || (=Tourist) || (=IC_BCG_Ireland) || (=VAF)</td></tr>
<tr><td></td><td>PM4</td><td>Person. Marital status</td><td>Single, Separated, Partner, Divorced, Married, Engaged, Widowed</td><td>(<AC_BCG_Countries) || (=Tourist) || (=IC_BCG_New Zealand) || (=VAF)</td></tr>
<tr><td></td><td>PON</td><td>Person. Official given name</td><td>In Kanji</td><td>((=AC_BCG_China) || (=AC_BCG_Japan)) || (<Visa type list) || (=IC_BCG_South Korea) || (=VAF)</td></tr>
<tr><td></td><td>PG</td><td>Person. Gender</td><td>Female, Male</td><td>(<AC_BCG_Countries) || (<Visa type list) || ((=IC_BCG_South Korea) || (=IC_BCG_Ireland)) || (=VAF)</td></tr>
<tr><td></td><td>PG2</td><td>Person. Gender</td><td>Female, Male</td><td>(<AC_BCG_Countries) || (=Tourist) || (=IC_BCG_New Zealand) || (=VAF)</td></tr>
</table>

Let us assume that there is a need to update existing CCL (presented in Table 6) with BBIEs identified in a new integration use case—*VAF of New Zealand for tourist visa type* [62]. A portion of the resulting CCL is presented in Table 10.

As a result, the integration analyst would get superfluous BIEs because the E-UCM supports Business Context-based search, but not dictionary information-based search (see Fig. 7). Namely, new BBIEs *Person. Family name* (ID='PFN2'), *Person. Birth* (ID='PB4') and *Person.*

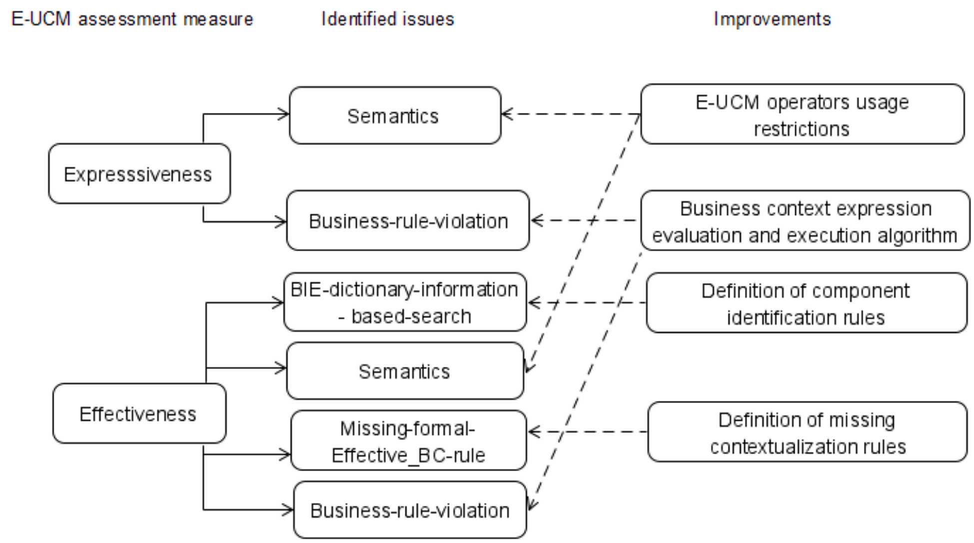

Fig. 13. Feasibility assessment results—summary (dash arrows indicate improvement targets).

Gender (ID='PG2') would be added even though adequate ones have already existed in the CCL. The BBIE *Person. Marital status* (ID='PM4') would be the only one correctly added since there are no existing BBIEs with the same dictionary information. (***BIE-dictionary-information-based-search issue***).

As shown in Fig. 12, four message schema profiles were assembled - one for each interested integration use case. The integration analyst has compared these message schema profiles with the expected outcomes and came to the conclusion that two message schema profiles (*VAF_Thailand* and *VAF_South Korea*) completely reflect the information that is supposed to be exchanged via corresponding message flow in a specific integration use case. For example, calculation of Effective_BC has recognized that BBIE *Person. Official Given Name* is irrelevant for *VAF_Thailand*, but it is relevant for *VAF_South Korea* only.

However, the calculation of Effective_BC has failed to recognize the correct BBIE *Person. Birth* in *VAF_Ireland_Tourist* message schema profile (both BBIEs with ID='PB2' and ID='PB3' are found in this message schema profile). In addition, it failed to recognize that BBIE *Person. Gender* is irrelevant for *VAF_Ireland_Temporary worker* message schema profile. These situations happened as consequences of the previously mentioned ***Semantics issue***. Consequently, Effective_BC for those BBIEs in both integration use cases (*VAF of Ireland for tourist visa type* and *VAF of Ireland for temporary worker visa type*) were calculated as not null, thus they were interpreted as relevant.

Let us, finally, consider the following hypothetical *VAF_New Zealand* message schema profile and its Required_BC. If the Required_BC for *VAF_New Zealand* message schema profile is defined as follows:

Example 3: (<AC_BCG_Countries) || (<Visa types) || (=IC_BCG_New Zealand) || (=VAF),

It would mean that it is relevant to an applicant coming from any country in the world, and for any New Zealand visa type. If the integration analyst would want to use this message schema profile for the following integration use case:

Example 4: (=AC_BCG_Somalia) || (=Temporary worker) || (=IC_BCG_New Zealand) || (=VAF), the Effective_BC for *VAF_New Zealand* message schema profile would be:

Example 5: (=AC_BCG_Somalia) || (=Temporary worker) || (=IC_BCG_New Zealand) || (=VAF)

Since the Effective_BC is not an empty set, this would mean that *VAF_New Zealand* message schema profile is valid for the Business Context in *Example 4*. However, the result is not correct since it violates business rules presented in Table 4. According to those business rules Somali applicants are not eligible to apply for a visa issued by New Zealand [61]. If business rules were considered, the Effective_BC would be an empty set. This situation is another consequence of the previously explained ***Business-rule-violation issue***.

Finally, the E-CCTS did not provide formal rules for the calculation of Effective_BC. This paper reversed engineered a set of top-down rules from the example provided in E-CCTS. Details about this issue are provided in Appendix A. (***Missing-formal-Effective_BC-rule issue***)

7. Discussion and future work

For each integration use case, the expressiveness and effectiveness of the E-UCM model have been assessed. In most integration use cases, E-UCM gave the expected results. However, there is a list of identified issues in each assessment measure that requires the four improvements to E-UCM and the underlying E-CCTS models. These improvements are outlined in Fig. 13 as the future work and are discussed below.

First, E-UCM Business Context expression and use of operators need to be modified in order to avoid the semantics issue. Particularly, the aim is to introduce the usage of logical operators on two levels: on the level of a single integration use case, and on the level of a whole graph (complete list of possible integration use cases). Each integration use case modeled using the modified context methodology should be represented as an n-tuple of categorized sets values (i.e., values that belong to the same Business Context category).

At the level of an integration use case, Business Context may be expressed using predicates proposed in [36] with the restriction that the operations between Business Context clauses of different categorized sets are disallowed. In other words, elements of compound Business Context clauses may only be Business Context scheme nodes associated with the same Business Context category.

At the level of the whole graph, a list of possible integration use cases must be a union of n-tuples describing individual integration use cases. The analysis showed that the union is the only appropriate set operator that summarizes distinct integration use cases. It follows that an integration use case is covered if its Business Context expression is a subset of any n-tuple in the union (i.e., Effective_BC is non-empty in all of the context categories specified in the Assigned_BC).

Second, a novel algorithm for Business Context expression evaluation and execution will be developed. As inputs, this algorithm would get Business Context clause for each employed Business Context category. An output of the algorithm would be a list of possible context paths—that do not violate any business rule. For this purpose, we will define a formalized mathematical framework for the evaluation of logical expressions and the segregation of acceptable context paths based on propositional calculus and graph theory.

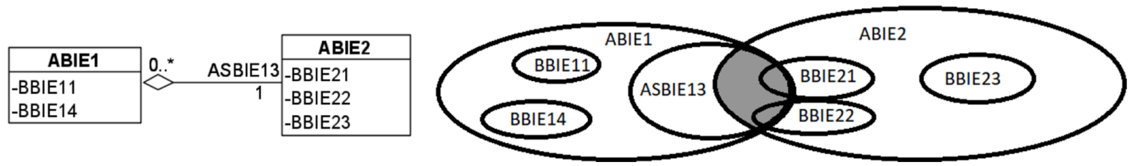

Fig. A. 1. . E-CCTS contextualization rules.

Third, a set of component identification rules that take into account the dictionary information will be defined. These rules provide improvements beyond E-UCM in that they allow for correct BIE reuses and enhanced BIE reusability when new integration use cases emerge. In particular, they will determine whether an existing component in the CCL with the requested dictionary information exists and can be reused. They should contribute to a better control of CCL growth.

Fourth, a set of formal rules for the Effective_BC calculation will be developed following the modified Business Context expression in the first future work. This was not provided in the E-UCM and it is important for reliable message schema profiling.

Finally, BCOnt, which is another promising Business Context model, will be investigated in a similar assessment and for possible incorporation into the overall approach for Business Context-based DES usage specification management.

8. Conclusion

The paper pointed out that the outdated DES and usage specification management processes impact the complexities and costs of systems integration. For scoping reasons, the paper focused on the improvement of the DES usage specification management, which includes development and reuse, and assumed that the DES (i.e., core components) were readily available through a compatible DES development process. While there were prior approaches to improve the DES usage management process, none of them had been successfully validated. One of the major issues with those approaches is that there is no provision for reusing the existing usage specifications. To address this issue, an envisioned Business Context-based approach was outlined. The approach requires business context models. Therefore, three existing business context models—namely UCM, E-UCM, and BCOnt—were reviewed; and a detailed assessment approach was proposed. This research took a closer look at E-UCM in particular, which is the most advanced model based on the prior UCM and E-CCTS. The assessment required calculation of Effective_BC. Since the calculation of Effective_BC was not provided by the E-CCTS, this paper reversed engineered a set of top-down rules from the example provided in E-CCTS. As a result of the assessment, modifications to E-UCM were described and proposed as the next steps in our future work. These identified modifications contribute to the future development of the DES and usage specification management system. The proposed assessment approach is generic and can be used to assess other business context models. In particular, it will be used to assess BCOnt to inform future development of such a system as well.

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Disclaimer

Certain commercial software products are identified in this paper. These products were used only for demonstration purposes. Their use does not imply approval or endorsement by NIST, nor does it imply these products are necessarily the best available for the purpose.

CRediT authorship contribution statement

Elena Jelisic: Conceptualization, Methodology, Writing – original draft. **Nenad Ivezic:** Methodology, Writing – original draft. **Boonserm Kulvatunyou:** Methodology, Writing – review & editing. **Pavle Milosevic:** Validation, Writing – original draft. **Sladjan Babarogic:** Supervision. **Zoran Marjanovic:** Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A: E-CCTS contextualization rules

The E-CCTS introduced three new rules for contextualization of BCCs, ACCs and ASCCs—Rule 2.4.1, Rule 2.4.2 and Rule 2.4.3 [36]. Each of these rules will be explained using the Set Theory. On the left-hand side in Fig. A. 1, a simple example, with two ABIEs and corresponding ABIEPs (BBIEs and ASBIEs), is presented. On the right-hand side, in the same figure, Business Contexts for each of these BIEs are presented using a Venn diagram. Each ellipse depicts an associated Business Context, in which the corresponding BIE is valid for use.

According to Rules 2.4.1 and 2.4.3, each BBIE and ASBIE has one Assigned_BC (e.g., sets $BBIE_{11}$ and $ASBIE_{13}$ on the right-hand side in Fig. A. 1 are the Assigned_BCs of the corresponding BBIE and ASBIE). Following the same rules, all BIEs have Overall_BC, as well. Since BBIEs are not compound, their Overall_BCs are the same as their Assigned_BCs. The Overall_BC of an ASBIE is calculated as an intersection of its Assigned_BC and Overall_BC of its associated ABIE ($ABIE_2$, in this example). In the observed example, the Overall_BC of the $ASBIE_{13}$ is marked as gray. In this case, the $ASBIE_{13}$'s Overall_BC determines which components will be used to describe the associated $ABIE_2$. In other words, the Overall_BC of the $ASBIE_{13}$ narrows the Overall_BC of the associated $ABIE_2$ and, consequently, affects the list of ABIEPs that describe the associated $ABIE_2$.

According to Rule 2.4.2, ABIEs do not have Assigned_BC, but only Overall_BC that is calculated as a union of Overall_BCs of its ABIEPs. For example, the $ABIE_1$ set on the right-hand side in Fig. A. 1 is the Overall_BC of the corresponding ABIE. In case of an ABIE, its Overall_BC determines which ABIEPs will describe that ABIE in a certain integration use case. For $ABIE_1$ all ABIEPs will be used since their Business Contexts completely intersect with the ABIE's Overall_BC; however, the $ABIE_1$'s Overall_BC can also be narrowed, as it was the case with $ABIE_2$. Note that the Overall_BC is calculated in a bottom-up manner.

In order to support profiling processes, calculation of Effective_BC as a specific contextualization construct is introduced. Effective_BC is supposed to make the profiling process more reliable through mathematical calculations, thus eliminating the need for subjective interpretations of component's Overall_BC. As a result, Effective_BC should inform us of BIE's relevancy/irrelevancy for a specific integration use case. In the E-CCTS description, there is no specific rule that defines the Effective_BC calculation. This calculation presented here is a reverse engineering of examples presented in [36] (***Missing-formal-Effective_BC-rule issue***). The same example from the Fig. A. 1 will be employed to explain two usages of Effective_BC calculation.

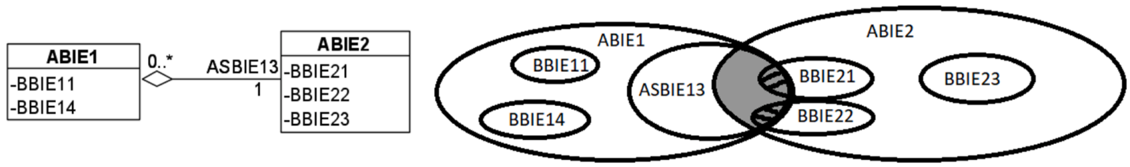

Fig. A. 2. . Calculation of effective Business Context - Effective part of associated ABIE.

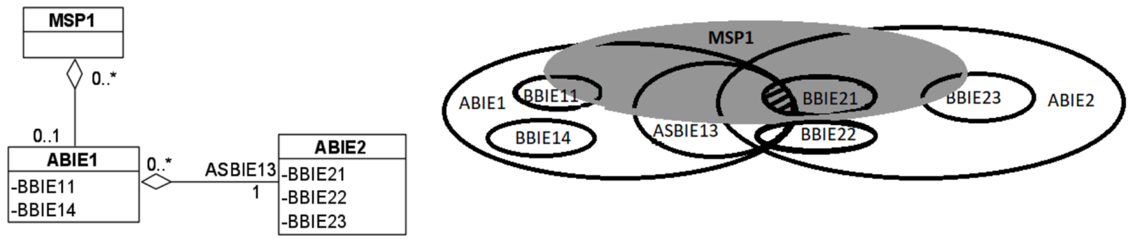

Fig. A. 3. . Calculation of effective Business Context - Effective part of message schema profile.

In the first usage, the Effective_BC identifies ABIEPs needed for an associated ABIE. As previously stated, the Overall_BC of $ASBIE_{13}$ narrows the Overall_BC of the associated $ABIE_2$ and, consequently, affects the list of ABIEPs that will be used to describe that associated $ABIE_2$. This usage will be denoted as *Effective part of associated ABIE*. The Effective_BC of an associated $ABIE_2$ is calculated as an intersection between its Overall_BC and the $ASBIE_{13}$'s Overall_BC. This narrowing of the $ABIE_2$'s Overall_BC affects the list of its ABIEPs. Further, Effective_BC for each ABIEP from the associated $ABIE_2$ can be calculated as an intersection of ABIEPs Overall_BC and Effective_BC of the $ABIE_2$. In Fig. A. 2, the Effective_BC of the $ABIE_2$'s ABIEPs is marked with hatched lines. In this example, Business Contexts of the $BBIE_{21}$ and $BBIE_{22}$ partially intersect with $ABIE_2$'s Effective_BC and, consequently, will be treated as relevant for the observed association. (Note that the Effective_BC for the $BBIE_{23}$ is an empty set and, consequently, it is not relevant for $ASBIE_{13}$ association.)

The second usage is to identify BIEs that are valid for a message schema profile. This usage will be denoted as *Effective part of message schema*. The Required_BC in which the message schema profile MSP_1 is valid is represented as a gray set in Fig. A. 3 and it "effectively narrows" the Overall_BC of the BIEs that are found in a corresponding logical message schema structure [36]. In other words, the Effective_BC of each BIE is calculated as an intersection between its Overall_BC and Required_BC of the MSP_1 (gray parts of the corresponding BIE's set represent its Effective_BC). However, this usage of the Effective_BC does not exclude calculation of Effective part of associated ABIE. Moreover, the narrowed Business Context of the $ASBIE_{13}$ further narrows the Business Context of the associated $ABIE_2$ (which can also be narrowed by the MSP_1's Required_BC) and, consequently, affects the list of ABIEPs that will be used to describe that associated $ABIE_2$ (the Effective_BCs of the $ABIE_2$'s ABIEPs are marked with hatched lines). As it can be seen, Effective_BC of the $BBIE_{22,}$ after applying Effective part of message schema calculation, is an empty set. This means that although it is relevant for $ASBIE_{13}$ in the general case, it is not relevant inside MSP_1. Note that the $BBIE_{23}$ is relevant for MSP_1 (there is an intersection between $BBIE_{23}$'s Overall_BC and MSP_1's Required_BC), but it is not relevant for observed $ASBIE_{13}$.

Calculation of Effective_BC for message schema profile was not provided by the E-CCTS. This paper reversed engineered a set of top-down rules from the example provided in E-CCTS and applied them to the message schema profiling in the feasibility assessment. This issue is identified as (***Missing-formal-Effective_BC-rule issue***) for E-UCM as E-CCTS derivative work, and it will be one of the future works to formalize these rules.

References

[1] E. Hartono, X. Li, K.S. Na, J.T. Simpson, The role of the quality of shared information in interorganizational systems use, Int. J. Inf. Manag. 30 (2010) 399–407, https://doi.org/10.1016/j.ijinfomgt.2010.02.007.

[2] I. Zikra, J. Stirna, J. Zdravkovic, A quality-driven methodology for information systems integration, Complex Syst. Inf. Model. Q. (2017) 39–65, https://doi.org/10.7250/csimq.2017-12.03.

[3] G. da Silva Serapião Leal, W. Guédria, H. Panetto, An ontology for interoperability assessment: a systemic approach, J. Ind. Inf. Integr. (2019) 16, https://doi.org/10.1016/j.jii.2019.07.001.

[4] W. Tan, W. Shen, S. Member, L. Xu, B. Zhou, L. Li, A business process intelligence system for enterprise process performance management, IEEE Trans. Syst. Man, Cybern. Part C (Applications Rev. 38 (2008) 745–756.

[5] X.H. Lu, L.H. Huang, M.S.H. Heng, Critical success factors of inter-organizational information systems - A case study of Cisco and Xiao Tong in China, Inf. Manag. 43 (2006) 395–408, https://doi.org/10.1016/j.im.2005.06.007.

[6] B.J. Hicks, Lean information management: understanding and eliminating waste, Int. J. Inf. Manag. 27 (2007) 233–249, https://doi.org/10.1016/j.ijinfomgt.2006.12.001.

[7] A. White, E.M. Daniel, M. Mohdzain, The role of emergent information technologies and systems in enabling supply chain agility, Int. J. Inf. Manag. 25 (2005) 396–410, https://doi.org/10.1016/j.ijinfomgt.2005.06.009.

[8] S. Narayanan, A.S. Marucheck, R.B. Handfield, Electronic data interchange: research review and future directions, Decis. Sci. 40 (2009) 121–163, https://doi.org/10.1111/j.1540-5915.2008.00218.x.

[9] W. Behrman, Best practices for the development and use of XML data interchange standards, Cent. Integr. Facil. Eng. Tech. Rep. 131 (2002) 27.

[10] M. L, A.O. K, The IFC standard: a review of History, development, and standardization, information technology, J. Inf. Technol. Constr. 17 (2012) 135–161.

[11] M.L. Marsal-Llacuna, M. Wood-Hill, The Intelligenter method (III) for "smarter" standards development and standardisation instruments, Comput. Stand. Interfaces. 50 (2017) 142–152, https://doi.org/10.1016/j.csi.2016.09.010.

[12] H. Liang, Y. Xue, T.A. Byrd, R.K. Rainer, Electronic data interchange usage in China's healthcare organizations: the case of Beijing's hospitals, Int. J. Inf. Manag. 24 (2004) 507–522, https://doi.org/10.1016/j.ijinfomgt.2004.08.001.

[13] R. Angeles, C.L. Corritore, S.C. Basu, R. Nath, Success factors for domestic and international electronic data interchange (EDI) implementation for US firms, Int. J. Inf. Manag. 21 (2001) 329–347, https://doi.org/10.1016/S0268-4012(01)00028-7.

[14] H.J. Ahn, P. Childerhouse, G. Vossen, H. Lee, Rethinking XML-enabled agile supply chains, Int. J. Inf. Manag. 32 (2012) 17–23, https://doi.org/10.1016/j.ijinfomgt.2011.06.002.

[15] A. Wasala, J. Buckley, R. Schäler, C. Exton, An empirical framework for evaluating interoperability of data exchange standards based on their actual usage: a case study on XLIFF, Comput. Stand. Interfaces. 42 (2015) 157–170, https://doi.org/10.1016/j.csi.2015.05.006.

[16] Y. Kabak, A. Dogac, A survey and analysis of electronic business document standards, ACM Comput. Surv. (2010) 42, https://doi.org/10.1145/1670679.1670681.

[17] Core Components Technical Specification CCTS, version 3.0., (2009) 162. https://unece.org/DAM/cefact/codesfortrade/CCTS/CCTS-Version3.pdf (accessed March 10, 2021).

[18] OAGIS 9 Naming and Design Rules Standard, (2005). https://oagi.org/Portals/0/Downloads/ResourceDownloads/OAGIS_90_NDR.pdf (accessed April 15, 2021).

[19] UBL Conformance to ebXML CCTS ISO/TS 15000-5:2005, (2014). http://docs.oasis-open.org/ubl/UBL-conformance-to-CCTS/v1.0/UBL-conformance-to-CCTS-v1.0.html.
[20] Core Components Library, (2021). https://unece.org/trade/uncefact/unccl (accessed May 19, 2021).
[21] B. (Serm) Kulvatunyou, H. Oh, N. Ivezic, S.T. Nieman, Standards-based semantic integration of manufacturing information: past, present, and future, J. Manuf. Syst. 52 (2019) 184–197, https://doi.org/10.1016/j.jmsy.2019.07.003.
[22] OAGi Releases OAGIS 10.7.1 and Score 2.1, (2021). https://oagi.org/NewsEvents/NewsandArticles/OAGISReleases1071andScore21/tabid/323/Default.aspx.
[23] H. Panetto, M. Zdravkovic, R. Jardim-Goncalves, D. Romero, J. Cecil, I. Mezgár, New perspectives for the future interoperable enterprise systems, Comput. Ind. 79 (2016) 47–63, https://doi.org/10.1016/j.compind.2015.08.001.
[24] L.Da Xu, Enterprise and supply chain architecture, Enterp. Integr. Inf. Archit. (2020) 148–185, https://doi.org/10.1201/b17156-7.
[25] A. Bucchiarone, A. Marconi, M. Pistore, H. Raik, A context-aware framework for dynamic composition of process fragments in the internet of services, J. Internet Serv. Appl. 8 (2017), https://doi.org/10.1186/s13174-017-0057-0.
[26] L.Da Xu, E.L. Xu, L. Li, Industry 4.0: state of the art and future trends, Int. J. Prod. Res. 56 (2018) 2941–2962, https://doi.org/10.1080/00207543.2018.1444806.
[27] C.S. Tang, L.P. Veelenturf, The strategic role of logistics in the industry 4.0 era, Transp. Res. Part E Logist. Transp. Rev. 129 (2019) 1–11, https://doi.org/10.1016/j.tre.2019.06.004.
[28] Kagermann, W.Wahlster, J. Helbig, Recommendations for implementing the strategic initiative INDUSTRIE 4.0, Final Rep. Ind. 4.0 WG. (2013).
[29] R. Winter, R. Fischer, Essential layers, artifacts, and dependencies of enterprise architecture, in: Proc. - 2006 10th IEEE Int. Enterp. Distrib. Object Comput. Conf. Work. EDOCW2006, 2006, pp. 30–38, https://doi.org/10.1109/EDOCW.2006.33.
[30] L.Da Xu, Engineering informatics and industrial information integration engineering, in: Proc. - 2nd Int. Conf. Enterp. Syst. ES 2014, 2014, pp. 232–236, https://doi.org/10.1109/ES.2014.33.
[31] L.Da Xu, Industrial information integration – An emerging subject in industrialization and informatization process, J. Ind. Inf. Integr. 17 (2020) 7–8, https://doi.org/10.1016/j.jii.2020.100128.
[32] Y. Chen, Industrial information integration—A literature review 2006–2015, J. Ind. Inf. Integr. 2 (2016) 30–64, https://doi.org/10.1016/j.jii.2016.04.004.
[33] N. Li, L. Zhao, C. Bao, G. Gong, X. Song, C. Tian, A real-time information integration framework for multidisciplinary coupling of complex aircrafts: an application of IIIE, J. Ind. Inf. Integr. (2021) 22, https://doi.org/10.1016/j.jii.2021.100203.
[34] K. Varnavskiy, F. Nepsha, Q. Chen, The assessment of functional efficiency of technological structure for the coal mine working face – an application of IIIE, J. Ind. Inf. Integr. (2022) 26, https://doi.org/10.1016/j.jii.2021.100262.
[35] G.D. Abowd, A.K. Dey, P.J. Brown, N. Davies, M. Smith, P. Steggles, Towards a better understanding of context and context-awareness, Lect. Notes Comput. Sci. (Including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics). 1707 (1999) 304–307, https://doi.org/10.1007/3-540-48157-5_29.
[36] D. Novakovic, Business Context Aware Core Components Modeling, Vienna University of Technology, 2014. https://publik.tuwien.ac.at/files/PubDat_234005.pdf.
[37] R.C. Motta, K.M. de Oliveira, G.H. Travassos, A conceptual perspective on interoperability in context-aware software systems, Inf. Softw. Technol. 114 (2019) 231–257, https://doi.org/10.1016/j.infsof.2019.07.001.
[38] A.M. Kosek, A.A. Syed, J.M. Kerridge, RDF recipes for context-aware interoperability in pervasive systems, in: Proc. - IEEE Symp. Comput. Commun, 2010, pp. 1017–1022, https://doi.org/10.1109/ISCC.2010.5546647.
[39] T. Moser, S. Biffl, Semantic Integration of Software and Systems Engineering Environments, IEEE Trans. Syst. Man, Cybern. Part C Appl. Rev. 42 (2012) 38–50.
[40] J. Guo, L. Xu, Z. Gong, C.P. Che, S.S. Chaudhry, Semantic inference on heterogeneous e-marketplace activities, IEEE Trans. Syst. Man, Cybern. Part A Syst. Humans. 42 (2012) 316–330, https://doi.org/10.1109/TSMCA.2011.2162946.
[41] S. Li, L.Da Xu, S. Zhao, 5G internet of things: a survey, J. Ind. Inf. Integr. 10 (2018) 1–9, https://doi.org/10.1016/j.jii.2018.01.005.
[42] O. Lehmann, M. Bauer, C. Becker, D. Nicklas, From home to world - Supporting context-aware applications through world models, in: Proc. - Second IEEE Annu. Conf. Pervasive Comput. Commun. PerCom, 2004, pp. 297–306, https://doi.org/10.1109/PERCOM.2004.1276867.
[43] D. Gil, A. Ferrández, H. Mora-Mora, J. Peral, Internet of things: a review of surveys based on context aware intelligent services, Sensors (Switzerland) 16 (2016) 1–23, https://doi.org/10.3390/s16071069.
[44] E. Jelisic, N. Ivezic, B. Kulvatunyou, S. Nieman, Z. Marjanovic, Business context-based quality measures for data exchange standards usage specification, 2021.
[45] E. Jelisic, N. Ivezic, B. Kulvatunyou, N. Anicic, Z. Marjanovic, A Business-Context-Based Approach For Message Standards Use - A Validation Study, Springer International Publishing, 2019. https://doi.org/10.1007/978-3-030-30278-8_35.
[46] Y. Yarimagan, A. Dogac, Semantics based customization of UBL document schemas, Distrib. Parallel Databases. 22 (2007) 107–131, https://doi.org/10.1007/s10619-007-7014-z.
[47] Y. Charalabidis, F. Lampathaki, D. Askounis, Unified data modelling and document standardization using core components technical specification for electronic government applications, J. Theor. Appl. Electron. Commer. Res. 3 (2008) 38–51, https://doi.org/10.4067/S0718-18762008000200004.
[48] F. Lampathaki, S. Mouzakitis, G. Gionis, Y. Charalabidis, D. Askounis, Business to business interoperability: a current review of XML data integration standards, Comput. Stand. Interfaces. 31 (2009) 1045–1055, https://doi.org/10.1016/j.csi.2008.12.006.
[49] Core components business document assembly technical specification, version 1.0., (2012). https://unece.org/DAM/cefact/TechnicalSpecifications/CCBDA_TS_v1.0.pdf (accessed April 10, 2021).
[50] ISO 3166-1:2020 Codes, (2020) 31. https://www.iso.org/standard/72482.html (accessed April 19, 2021).
[51] Unified context methodology technical specification, (2010). https://studylib.net/doc/7241720/un-cefact-unified-context-methodology-technical (accessed May 15, 2021).
[52] Unified context methodology (UCM) direction and concepts, (2009). https://www.oasis-open.org/committees/download.php/31796/ScottHinkelmann-UCM.pdf (accessed April 16, 2021).
[53] D. Novakovic, C. Huemer, Business context sensitive business documents : business context aware core components modeling using the E-UCM Model, in: 11th IEEE Int. Conf. Ind. Informatics, IEEE, Bochum, Germany, 2013: pp. 523–528.
[54] D. Novakovic, C. Huemer, Business context sensitive business documents: an ontology based business context model for core components, in: Proc. Tenth Int. Conf. Informatics Inf. Technol, 2013.
[55] International Standard Industrial Classification of All Economic Activities (ISIC), (2008). https://unstats.un.org/unsd/classifications/Econ/Download/InText/ISIC_Rev_4_publication_English.pdf (accessed June 19, 2021).
[56] South Korean visa application form, (2020). https://korea-visa-application-form.pdffiller.com/(accessed March 6, 2021).
[57] Thailand visa application form, (2020). http://www.thaiconsulatehouston.com/(accessed March 6, 2021).
[58] Irish employment visa application form, (2020). https://www.dfa.ie/(accessed March 6, 2021).
[59] Irish Tourist Visa Application Form, (2020). https://www.pdffiller.com/100096225-Ireland-Tourist-visa-applicationpdf-irish-visa-application- (accessed March 6, 2021).
[60] Travel visa, (2021). https://en.wikipedia.org/wiki/Travel_visa (accessed July 1, 2021).
[61] List of citizenships refused entry to foreign states, (2019). https://en.wikipedia.org/wiki/List_of_citizenships_refused_entry_to_foreign_states (accessed April 17, 2021).
[62] New Zealand tourist visa application form, (2015). https://www.pdffiller.com/100096225-Ireland-Tourist-visa-applicationpdf-irish-visa-application- (accessed March 6, 2021).